Predicting the Effect of Climate Change on a Marine Snail

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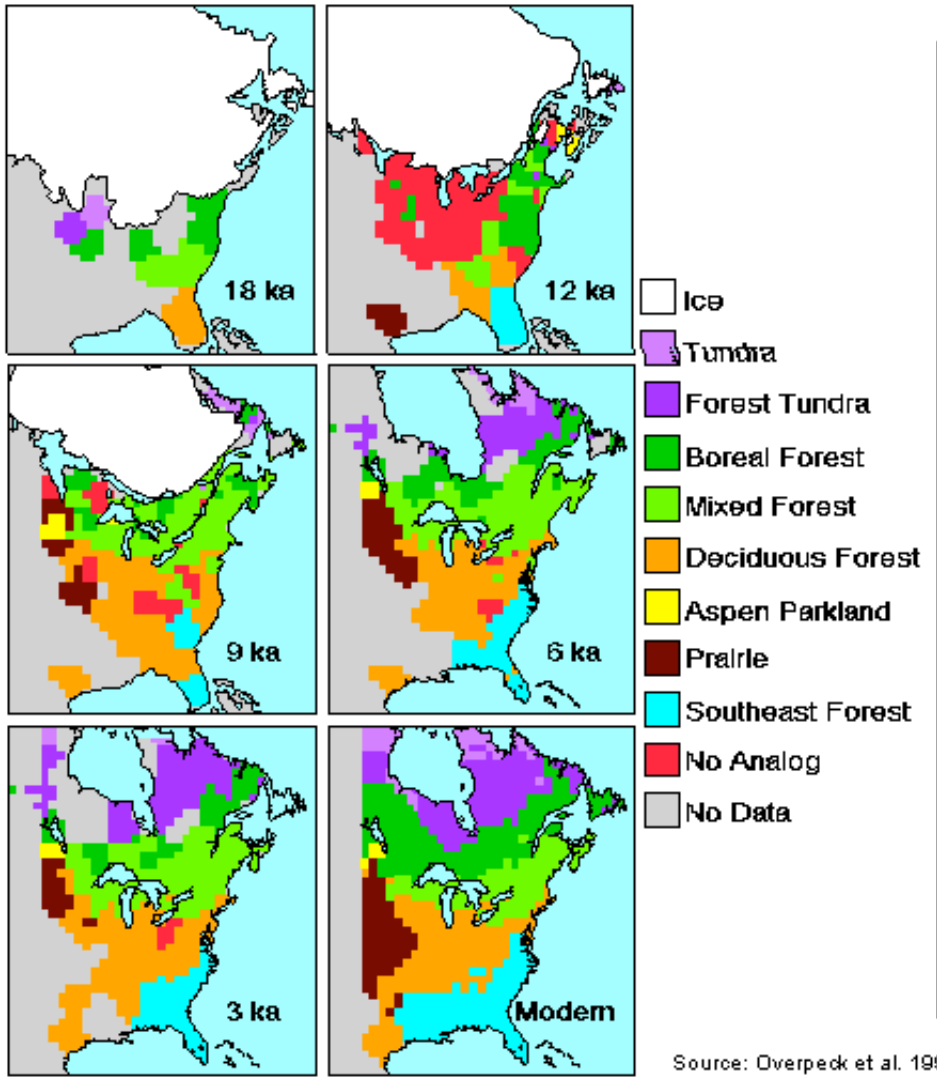
Although we are fairly certain that the climate is changing; we are only beginning to address the issue of how climate change will affect biological species and ecosystems. My research attempts to predict the response of an intertidal snail to climate change, specifically global warming, by examining the factors that determine the northern limit of its present geographic distribution.



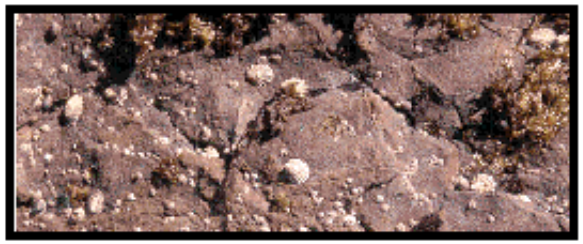
Source: Overpeck et al. 1992. Geology 20: 1071-1074

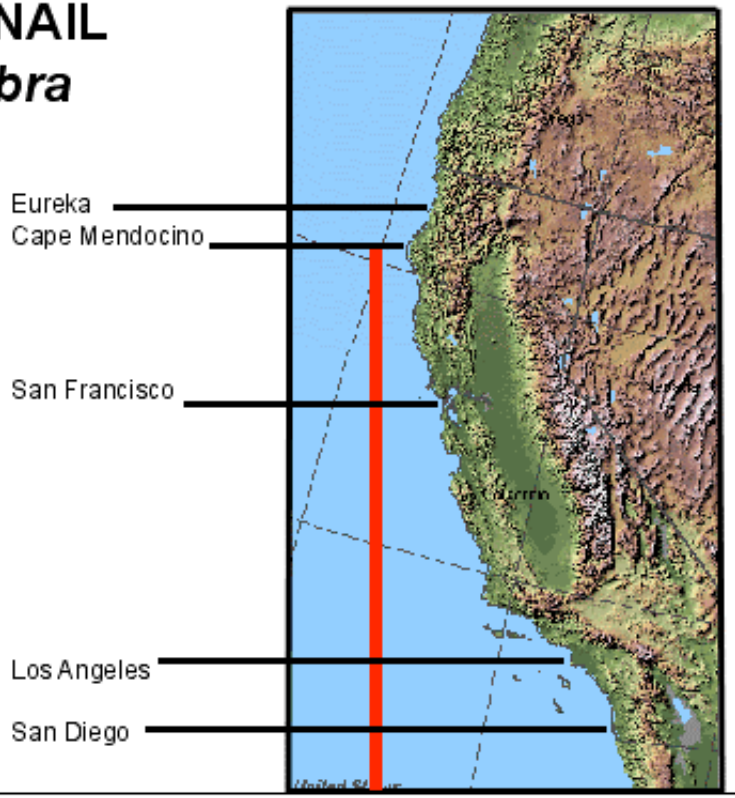
The simplest possible prediction is that species and communities in the northern hemisphere will simply migrate north as the climate warms up.

However an examination of past species' responses to climate change suggests a more complex response. Overpeck et al (1992) reconstructed plant communities over the past 18,000 years from fossil pollen data. As recently as 3000 years ago, they found combinations of species that are not analogous to any known modern plant community.

These "No Analog" communities indicate that species will respond individualistically to climate change. The reorganization of plant communities has strong consequences for other species.

THE INTERTIDAL SNAIL
Macclintockia scabra





My research directly tests the hypothesis that species will migrate north in response to climate change by examining the factors that determine the northern range limit of the intertidal snail *Macclintockia scabra*

The advantage of using a coastal species is that its distribution is compressed along the continental margin and it can only respond to climate change by moving north or south.

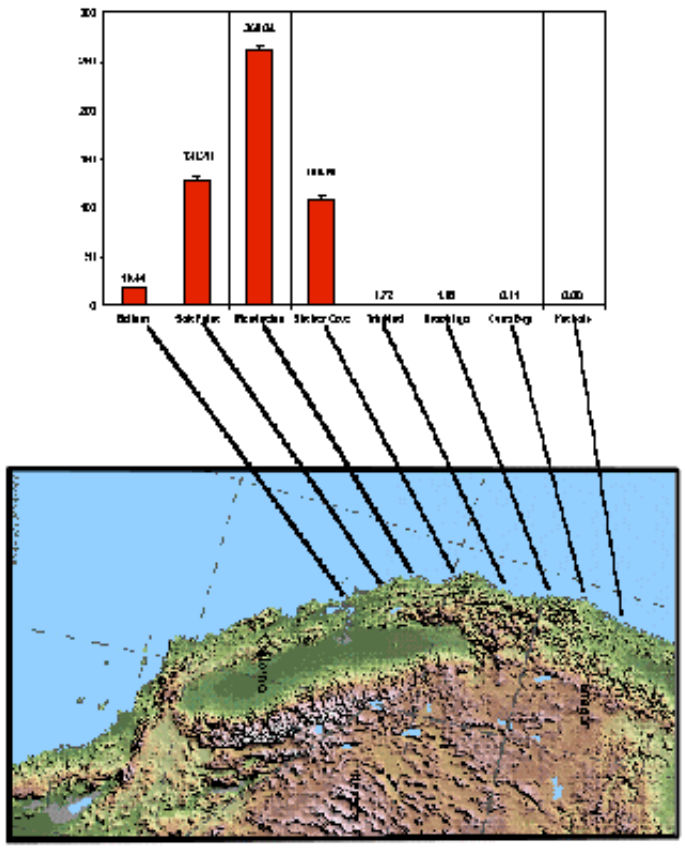
What sets the limits to *M. scabra's* geographic distribution?

There are three general kinds of factors:

1. Physiological tolerance of climate (e.g. temperature)
2. Mechanisms affecting the dispersal of snail larvae (e.g. ocean currents)
3. Ecological interactions with other species (e.g. predation or competition)

ALL OF THESE FACTORS COULD BE INFLUENCED BY CLIMATE CHANGE

The Abundance of *Macclintockia scabra* Across the Northern Range Limit

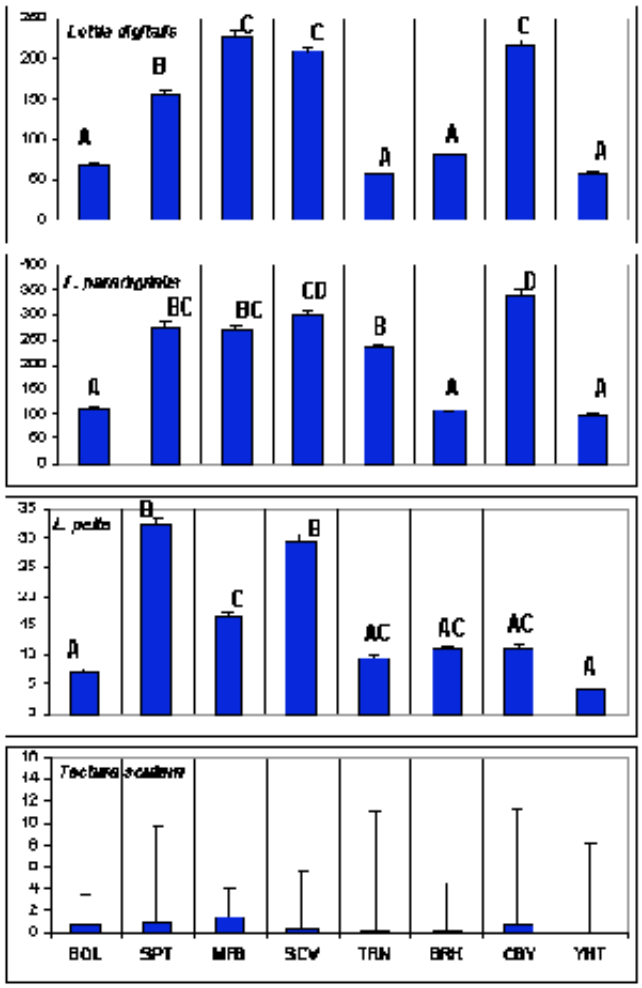


The first part of this project was an examination of the abundance of *M. scabra* across its northern range limit. My goal was to determine the exact location of the northern range limit and describe how abundances of *M. scabra* and other snails changed around the range limit.

I surveyed the abundance of snails in 160 20cm x 20cm quadrats at eight sites across northern California and southern Oregon.

I found a 10-fold decline in abundance between Site 4 (Shelter Cove, CA) and Site 5 (Trinidad, CA). Subsequent field surveys between these two sites identified the northernmost population at Cape Mendocino, CA.

Other Limpet Species



Along with *M.* scabra, I surveyed the abundance of four other snail species at these eight sites. These snails are all known to occur much further north (in some cases, well into Alaska)

I have plotted here the abundanced of four of these species. For the first three (*Lottia digitalis, L. paradigitalis,* and *L. pelta*) I used ANOVAs to test for differences in abundance at the different sites. The letters above each bar in the graphs indicate groups of mean abundances that are stastistically indistinguishable from each other.

Note that all three species show a statistically significant drop in abundance between Site 4 and Site 5.

This suggests that whatever factor causes *M. scabra* to decline at Cape Mendocino is also affecting other snails in the same way.

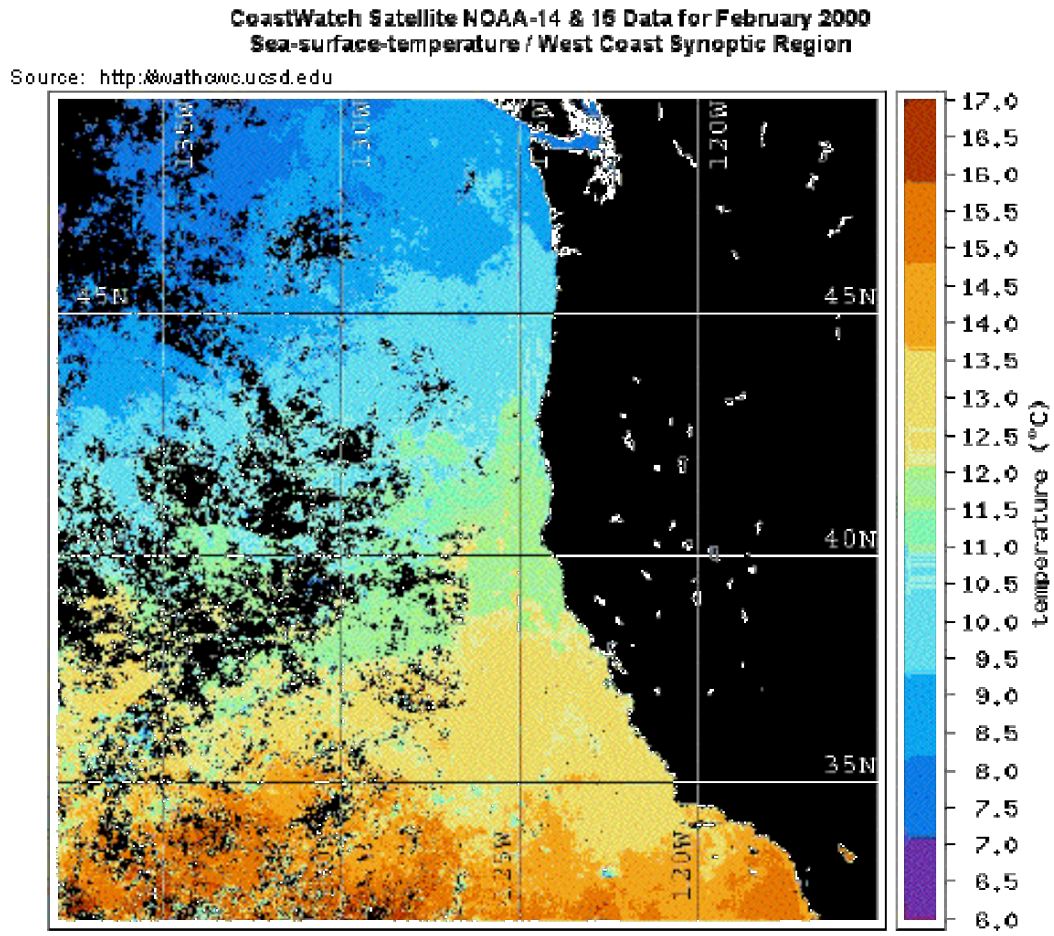
Summary: Survey of Abundance

- The northern range limit of *Macclintockia scabra* is approximately Cape Mendocino, CA (40.33°N, 120.29°W).

- The abundances of at least three other snails also decline sharply along this stretch of coast, although they increase again further north.

This is consistent with a hypothesis of a broadly acting abiotic factor controlling the northern range limit of *M. scabra*. Possible factors include climate (physiological stress) and ocean currents (dispersal).

Does Climate Determine the Northern Range Limit?



The figure at left shows sea surface temperature for February 2000, from NOAA satellite data. This figure clearly shows that water temperatures decrease with latitude along the west coast of the United States.

Consequently, it may be that the northern range limit of *M. scabra* is determined by conditions where temperatures become too cold for the snail to grow or survive.

The second part of my research tests this hypothesis with a transplant experiment of snails across the northern range limit.

Rationale

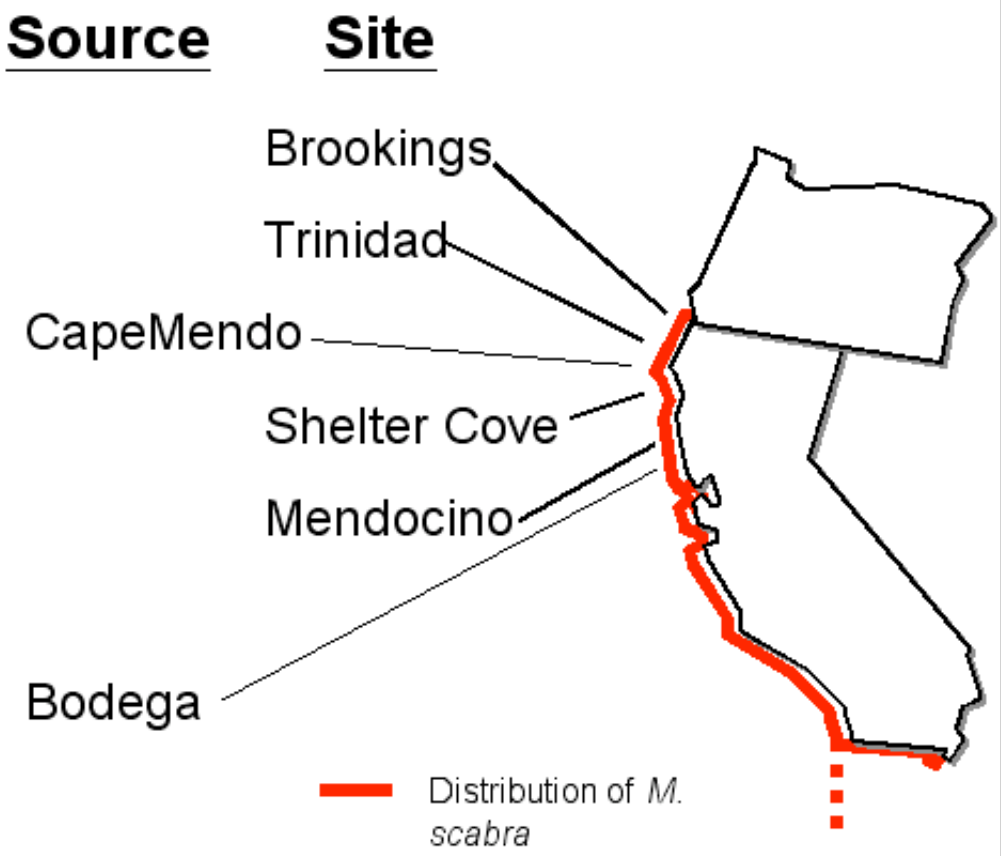
***If the northern limit is set by climate**:*

Snails transplanted north of Cape Mendocino will do worse than those transplanted south of Cape Mendocino

If factors other than climate are important for the northern range limit:

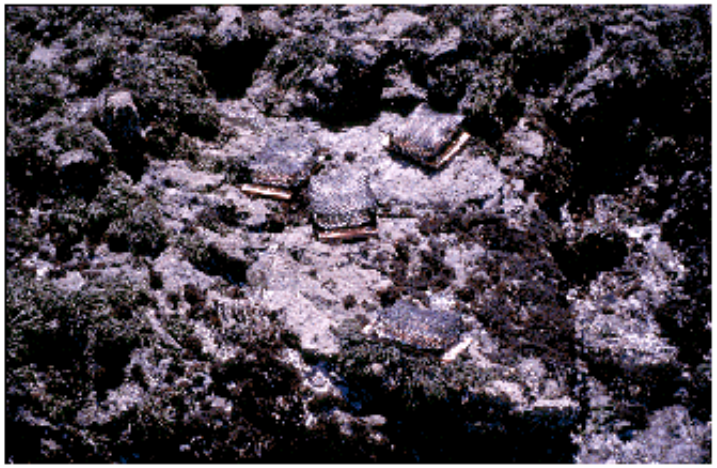
There will be no relationship between latitude and performance

Transplant Experiment



To test whether snails do not occur north of Cape Mendocino because they cannot grow or survive, I conducted a transplant experiment. I collected 320 snails from each of two locations: Cape Mendocino, near the edge of the range; and, Bodega Bay, near the center of the range. I individually tagged, measured, and weighed each snail and transplanted 80 snails from each source to each of four transplant sites. Two sites (Brookings, OR and Trinidad, CA) were north of the range limit and the remaining two were inside the species' range.

A Transplant Site

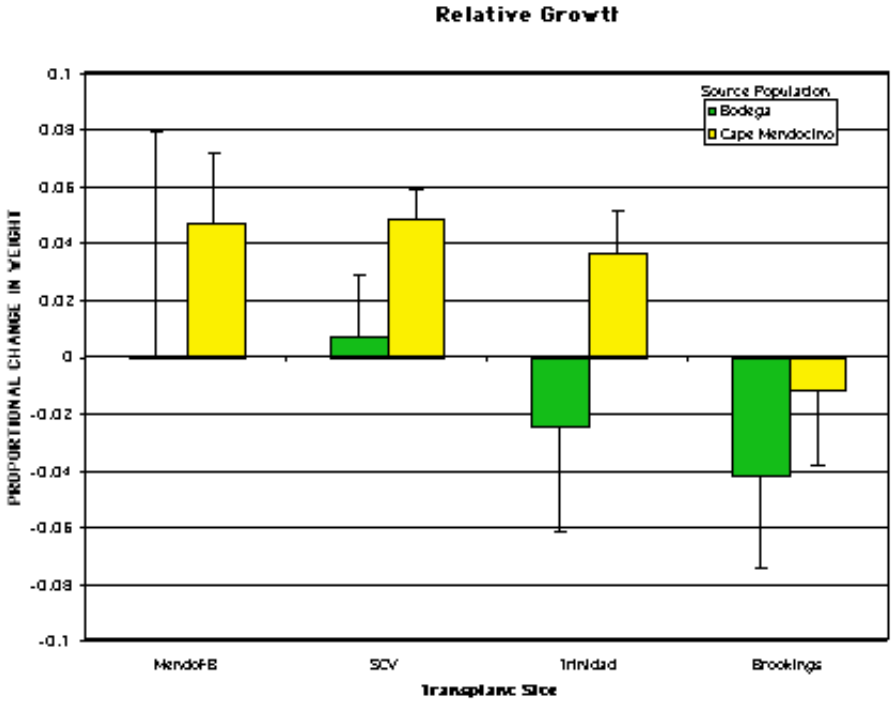


At each of my four transplant site, I set out 20 cages of 8 snails. All of the snails within a cage came from either the Cape Mendocino or Bodega Bay source population.

The cages were constructed from plywood, terra cotta tiles, and polyethylene mesh.

I set the cages in five blocks of four on rocky reefs at each site. Each cage was bolted down at each corner with a #10 x 1 1/2" stainless steell bolt, anchored into the rock.

Results



Analysis of Covariance

Source	df	SS	F	P
Initial weight (Covar)	1	0.18038	1305.42	<.0001
Source population	1	0.00104	7.56	0.0067
Transplant Site	3	0.00090	2.18	0.0925
Source x Site interaction	3	0.00009	0.21	0.8900

This first transplant experiment ran from October 1999 through January 2000. At the end of the experiment I reweighed each snail and analyzed changes in weight with an ANCOVA (below).

Plotting change in weight by source population (different colors) and transplant site (ordered from South to North along the x-axis) reveals some interesting patterns:

1) Growth rates differed between source populations

2) Growth did decline with latitude for both populations.

3) Growth did not decline sharply at the range limit for the northern (Cape Mendocino) population.

Conclusions

- The abundance of *M. scabra* declines sharply across Cape Mendocino. Concordant declines were observed in other limpet species. **This suggests an abiotic cause of the range limit, such as physiological stress or dispersal limitation.**
- Although snails transplanted extremely far north of the range limit did not grow, snails transplanted to just beyond the range limit grew just as well as those transplanted to sites within the range limit. **This suggests that climate does not influence the northern range limit of *Macclintockia scabra*.**
- The next part of the project will explore larval dispersal and settlement.